

1977

# White clover in Louisiana

Corbin Ransom Owen

Follow this and additional works at: <http://digitalcommons.lsu.edu/agexp>

---

## Recommended Citation

Owen, Corbin Ransom, "White clover in Louisiana" (1977). *LSU Agricultural Experiment Station Reports*. 127.  
<http://digitalcommons.lsu.edu/agexp/127>

This Article is brought to you for free and open access by the LSU AgCenter at LSU Digital Commons. It has been accepted for inclusion in LSU Agricultural Experiment Station Reports by an authorized administrator of LSU Digital Commons. For more information, please contact [gcoste1@lsu.edu](mailto:gcoste1@lsu.edu).

LOUISIANA STATE UNIVERSITY  
AND AGRICULTURAL AND MECHANICAL COLLEGE

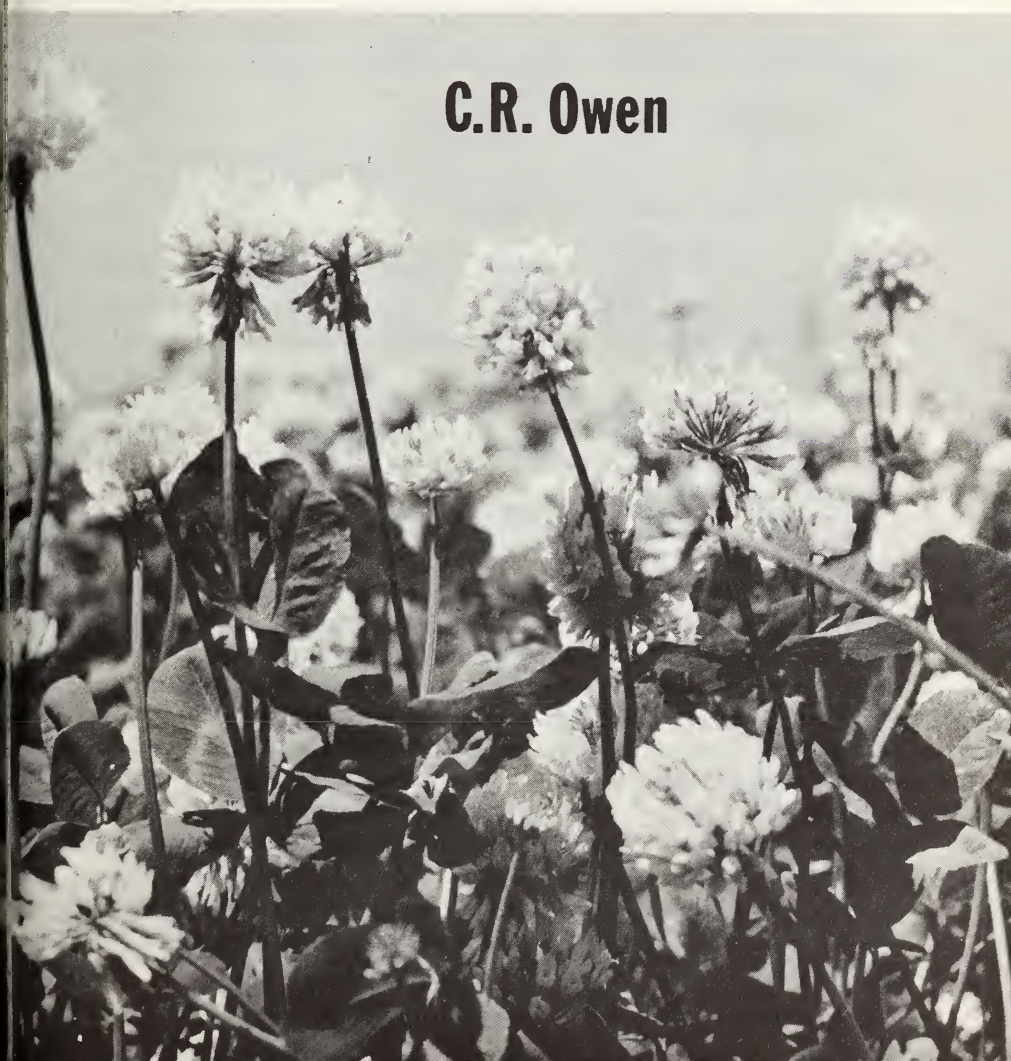
*Center for Agricultural Sciences  
And Rural Development*

AGRICULTURAL EXPERIMENT STATION  
DOYLE CHAMBERS, DIRECTOR

LSU LIBRARY--BR

# White Clover in Louisiana

C.R. Owen



## Contents

	Page
Introduction .....	3
Review of Literature .....	4
Materials and Methods .....	7
Breeding Methods .....	9
Further Experiments with Polycross Progenies .....	9
Variety Forage Yield Trials .....	9
Comparison of Forage Production and Flowering from Seed of Louisiana S-1 Produced in Oregon and in Louisiana .....	10
Effects of Seed Storage on Viability .....	10
Maintaining Foundation Breeding Stock .....	11
Results .....	12
The Synthetic Variety .....	12
A Further Experiment with Polycross Progenies .....	14
Comparison of Seed Head Size and Fertility of Florets .....	14
Forage Yield Trials with Varieties .....	17
Seasonal Forage Yields .....	17
Comparison of Forage and Seed Yields from Seed Produced in Oregon and Louisiana .....	18
Blooming Rate .....	21
Seed Production .....	21
Pollination .....	23
Seed Harvesting .....	23
Cleaning the Seed .....	24
Seed Storage .....	24
Insect Pests .....	25
Summary .....	26
Literature Cited .....	27

# White Clover Improvement in Louisiana

C. R. OWEN<sup>1</sup>

## Introduction

White clover (*Trifolium repens* L.) has contributed much to the development of grassland agriculture in Louisiana and the southern states. Although apparently little is known of its earliest use, reference is made to white clover during the 19th century (1)<sup>2</sup>. In an early Louisiana Agricultural Experiment Station Bulletin (1) there is this brief statement: "*Trifolium repens* (white clover) grows wild and luxuriantly all over the south and middle of Louisiana and affords our earliest spring pastures." Prior to comparatively recent times this crop has not been seeded by farmers but it has spread over much of south and central Louisiana by livestock, flood waters, and other natural means.

White clover is thought to have originated in the eastern Mediterranean countries or in Asia Minor. From there it spread throughout western Europe and eventually to other continents (13). In the Western Hemisphere, white clover is found growing from Alaska to southern South America. It is found on every continent and most of the major islands, including Greenland (13). It is thought to have been brought to the Western Hemisphere as seed in hay fed to livestock while they were on ships (17). The seed, being very small and incased in small pods attached in seed heads, were easily scattered by wind, flood waters, birds, and other natural means (17). Such widespread distribution of a species would be expected to give rise to many types of white clover, as is the case with corn and other cultivated crops. It is true that white clover is highly variable, and three types are recognized: (1) the large type known as Ladino; (2) the intermediate type represented by the regional variety Louisiana white clover and that acclimated in New Zealand, and (3) the low-growing type of which New York or New England wild white clover is an example. These types result from natural selection within certain regions of the temperate zones. The principal differences among them are in size and general performance. Ladino responds to day length in blooming, whereas the other types are less sensitive to the period of light for normal blooming and seed formation.

---

<sup>1</sup>Professor Emeritus, Department of Agronomy, LSU, Baton Rouge, La.

<sup>2</sup>Italic numbers in parentheses refer to Literature Cited, Page 27.



Considerable variation is present within all three types, and there is considerable overlapping in variability, at least between Ladino and the intermediate and between the intermediate and the small New England type.

A program of clover improvement was begun by the Louisiana Agricultural Experiment Station in 1945 for the purpose of producing varieties, strains, or types better suited for use in pastures. It was thought that development of varieties that would produce forage later into the summer would be a worthwhile objective. Improved varieties with the naturally reseeding characteristic should add substantially to the yield if an improved variety is used in pastures which are judiciously managed.

White clover improvement in Louisiana was not restricted to breeding but also included seed production, preparation of seed for marketing, and methods for storing. The protection of white clover from the various insect pests was also part of the program.

## Review of Literature

White clover (*Trifolium repens* L.) is considered to have originated in the eastern Mediterranean area or in Asia Minor, according to Gibson and Hollowell (17). They reported that it apparently spread rapidly throughout western Europe. Regarding its spread to the North American Continent, Carrier and Bart (11) concluded that evidence pointed to the fact that it was introduced early in the colonization period. They quote an early writer who stated that white clover accompanied the settlements of the white European so closely that it was known by the Indians as "white man's foot grass." Erath (13) reported the existence of stands of white clover on every continent and major island. In the tropics it is found at the higher elevations.

Attwood and Hill (2) reported on their investigation of meiosis in the microsporophytes of white clover and concluded that it probably was an amphidiploid rather than an autotetraploid and should show disomic inheritance. Attwood (3) reported on the genetics of cross-incompatibility among self-incompatible plants. In this report he said seed yield per head under bag is considered an excellent measure of compatibility. The two classes, compatibility and incompatibility, are very distinct. He stated further that the results from experiments with incompatible plants are best explained by the diploid personate type of multiple oppositional allelomorphs, where parents differ in both factors. Attwood (4) concluded from experiments with the oppositional alleles that cross-incompatibility between unrelated plants of white clover should be expected very rarely. Further studies by Attwood (5) revealed the presence of a factor for self-compatibility to be conditioned by a single gene for self fertility. It was reported to be a member of the multiple allelic series and dominant to the factors for self-incompatibility. Attwood and Sullivan (7) found in their studies with a cyanogenetic glucoside that its inheritance was conditioned by two com-

plementary dominant factors. White clover is recognized as a highly polymorphic species (8). It is largely self sterile, but carries a factor for self fertility,  $S_r$ , as well as factors for pseudo-self-fertility. The sterility factors number in excess of 35. Most plants occurring in nature should be cross-compatible.

Gibson (14) reported on results from experiments with day length or light period and blooming rates of white clover. The nonflowering clover under normal day length persisted longer than the same clover under the extended light period or the profusely flowering clover under the normal daylight period. The profusely flowering clover under extended light period persisted longer than the nonflowering clover under the normal daylight period. It was found in Louisiana (23) that Ladino white clover, the nonblooming type at the latitude of Baton Rouge, bloomed profusely when the light period was extended to 14 hours by the use of fluorescent lights. The persistency was not tested, but it was noted that the acclimated clover did not bloom so profusely at this extended light period. Gibson *et al.* (14) proposed the selection of nonviney types of clones over the viney types for persistence of the synthetic varieties formed from them. Gibson (14) proposed a method for evaluating white clover strains by transplanting seedlings into checks at intervals of 6 inches. The results from such plantings compared favorably with solid-seeded plots. This method provides a means of evaluating seed from hand crossing in the greenhouse.

The importance of midsummer diseases was reported by Halpin *et al.* (20). They stated that southern blight appeared to be closely associated with summer dieback. The plant material was destroyed by the fungi that initiate summer dieback. This dead material served as a substratum for the causal organism of southern blight. They further stated that selecting for resistance to the fungi that incite summer dieback should at least partially control southern blight.

Tisdal and Crandall (28) were among the first to report on the use of the polycross progeny performance as an index of combining ability of clones. Clones selected for high combining ability produced synthetic varieties superior to parent varieties in forage yield and definitely better than clones showing low combining ability in polycross progeny.

Interspecific hybrids were made by Gibson and Bienhart (18) between *Trifolium repens* (white clover) and a closely related species, *T. occidentale*. *T. occidentale* is a diploid with 16 pairs of chromosomes. *T. repens* has 32 chromosomes and is classed as amphidiploid (2). Success was reported from crossing colchicine-induced tetraploids of *T. occidentale*. Further studies with species hybrids were reported by Gibson *et al.* (19). These crosses involved another species, *Trifolium uniflorum* with 32 chromosomes, and a colchicine-induced tetraploid of *T. occidentale*. They were successful in combining the three species. They reported the trihybrid as moderately fertile. It was thought by them that these species had certain characteristics that would be desirable to add to white clover. *Trifolium*

*uniflorum* has a woody tap root, and *T. occidentale* has resistance to certain viruses.

Among the earlier workers with nitrogen fixation by legumes were Lyon and Bizzell (22). They grew legumes with oats and compared the forage with oats alone. It was found that oat yields were higher when grown with legumes than when oats were grown alone. They also reported an increase in the protein content of the oat forage. Gibson and Hollowell (17) reported the nitrogen fixed by white clover to be from 50 to 200 pounds per acre. Harlan (21) quoted from Sears in New Zealand, stating that a good sward of New Zealand white clover will fix nitrogen from the air equivalent in available N to 1 ton of ammonium sulfate (21 percent N) to the acre. Smith and Gibson (27) discussed the influence of temperature on growth and nodulation of white clover infected with bean yellow mosaic virus. Rhizobia inoculation increased clover yields at temperatures from 50° F to 86° F. They said virus infection decreased the beneficial effects of rhizobia at 62° F and above.

Barrett and Gibson (9) reported on the identification and prevalence of white clover viruses in pastures in the southeast. They stated that of 636 white clover plants collected from 19 pastures in 13 southeastern states, 237 were infected with one to three viruses.

Marble *et al.* (23) discussed seed production of Ladino white clover in California. They said the honeybee was the most effective pollinator of white clover and that most growers in that area use one "strong" hive per acre, although a few provide three or four such hives per acre. They added that, "results of recent tests strongly indicate that one to one and one-half strong hives per acre are sufficient for complete pollination." The behavior of honeybees in gathering nectar and pollen was studied by Singh (26). Individual bees were marked with quick-drying paint. The results reported indicated that individual honeybees restrict their activities to comparatively small areas. On alsike clover, he stated, "a single bee visited an area of 8 feet by 9 feet during a day and confined its total activities to an area of 41 feet by 31 feet."

The problems of storing seed of small-seeded legumes have been investigated by Clark and Bass (12). They reported on the effects of storage conditions, packaging materials, and moisture content on the longevity of crimson clover seed. The seed were dried to 5.0 and 6.9 percent moisture content, packaged in containers constructed of various heat sealable materials, and stored up to 11 years at a wide range in temperature and humidity. Materials containing foil afforded the best protection. Under favorable storage conditions, moisture barriers had little effect on the maintenance of germination.



## Materials and Methods

### Breeding Methods

The first phase of the work with breeding white clover was described previously (24). However, since that publication is out of print and the supply is about exhausted, a brief discussion of the initial phase of the work will be given.

A survey was made of pastures and white clover seed fields in August, 1945, in the Atchafalaya and Red River floodplains. The survey began near the mouth of the Atchafalaya river and extended to Alexandria. Seed heads were taken from wherever they were available. Not many fields or pastures visited had white clover growing during that season, but several hundred seed heads were collected. Those from each field were kept separate and each seed head was put into a small coin envelope.

The seed were separated from each head and counts were made of the number of seed per head. Seed from those heads with the larger number of seed were used for planting. The seedlings were started in greenhouse flats in January and transferred to 6-ounce paper cups when permanent root systems had formed. The seedlings were left in the greenhouse until the danger of a hard freeze had passed; they were set in the field into spaced rows 42 inches apart in drills of the same width in early April.

The nursery was established with seed from 64 seed heads. It was arranged in an 8 x 8 simple lattice experimental design with four replications. The seedlings were set in two-row plots of six hills per row. With the borders and rows planted outside the experimental area, there were more than 4,000 plants under observation in the first planting.

The nursery was cultivated and weeded until the seedlings were established. The nursery was kept free of tall-growing weeds by topping the area with a sickle bar mower.

The following October the percent survival was recorded and surviving plants were measured to determine the extent of spread and the degree of cover the plants had maintained. Finally, 25 clones were selected from the nursery to be transferred to a polycross nursery.

The polycross nursery was established in an isolated area. The plot size was 14 feet x 14 feet with alleys between. The experimental design was a 5 x 5 lattice square with three replications. The clones were transplanted in the center of the plots in an area 3½ feet x 3½ feet. They were allowed to spread toward the periphery of the large plots.

The clones were evaluated by determining the area covered during the growing season, the maintenance of forage over the area spread, forage yields, and seed yields. These observations were made during two seasons. Following these experiments, the seed of the more outstanding clones were planted in replicated forage and seed yield trials for estimation of their combining ability.



From these experiments, eight clonal lines were isolated. Five of these were combined to form the synthetic variety. This was done by transplanting clone propagules into spaced rows in clone-to-row order and arranging the rows at random with adequate replications to insure random pollination between all clonal lines. When the seed matured they were harvested en masse and thoroughly mixed in the process of cleaning.

After completion of the experiments with the original clones and testing of the synthetic variety, a second cycle clone nursery was established with seedlings from polycross seed of the more outstanding clones. The plan for this experiment was similar to that of the first. From this test some promising clones were isolated, but none was found to be sufficiently superior to the original clones to justify their replacement.

Later in the program, a third experiment was carried out with a collection of clones from areas north of Alexandria. Clonal propagules were taken from pastures and along highway rights-of-way. About 50 clone sections were collected from each of 25 locations; they were taken during late fall, brought to Baton Rouge, and planted in a nursery. They were allowed to spread in competition with the winter, spring, and summer grasses. Tall weeds were kept down by mowing periodically with the mower set above the clover.



**Figure 1. — Clone nursery for increasing clonal lines for the formation of the synthetic variety Louisiana S-1.**

## Further Experiments With Polycross Progenies

In 1960 an experiment was begun to compare forage and seed production of polycross progeny components with that of the synthetic variety from foundation seed. The experiment was planted on Olivier silt loam soil in late fall. The land was prepared, limed, and fertilized in accordance with that of other such experiments with white clover. The seed from the clones were produced in a polycross nursery in which only the six clonal components of the variety were included. The plot size was 7 feet square and there were four replications arranged in a randomized completed block design.

In 1961, forage harvests were made when the seed were mature. The plots were split and one-half of each plot area was harvested when the early flush of blooms were mature, or about May 15. The second half was harvested one month later. Forage at each harvest was mowed from the plot, bagged, weighed, and dried. The dry weights were taken and the seed threshed from each bag. Seed were separated from the forage and weighed. The plots were mowed later during the summer and fall to remove forage and weeds. In the spring of 1962, forage was harvested from the plots in March, and an application of 0-14-14 fertilizer was made at the rate of 600 pounds per acre. The plots were split as in the previous year, and one-half of each plot was harvested when the early flush of blooms had matured seed, or about May 15, and the second half was harvested one month later. The harvesting routine of the previous year was followed. Seed head size and fertility of florets were studied for each clonal line.

Seed head samples were taken from the experiment comparing forage and seed yields. Ten mature seed heads were taken at random from each of the 36 plots. Each head was placed into a separate small coin envelope, and the envelopes from each plot were put into separate paper bags. In the laboratory, the number of florets from each seed head was determined, and the florets containing seed were separated and counted. These samples were taken just prior to each forage harvest. The average number of florets per seed head and the percent of fertile florets were calculated.

## Variety Forage Yield Trials

Forage yield trials with varieties were conducted during most years of the white clover improvement program. The experimental designs were such that statistical treatment of the data was applicable. All variety tests were planted between October 15 and November 15. Rate of seeding was 5 pounds per acre, and the seed were inoculated before planting. The land was prepared by plowing, disking, harrowing, and rolling with a cultipacker. During the process of land preparation, lime and fertilizer were applied as specified by soil tests. The clover forage was harvested in April, May, and June. At harvest the forage was dried and weighed, and the yields reported as pounds of hay per acre (15 percent moisture).

These experiments were conducted to evaluate new strains produced in the breeding program. Standard varieties were usually used as checks. The varieties included in the yield trials were: Regal, a synthetic Ladino-type variety produced by the Alabama Agricultural Experiment Station; Tillman, a synthetic Ladino-type variety produced cooperatively by the Agricultural Research Service, U. S. Department of Agriculture, and the South Carolina Agricultural Experiment Station; Common Ladino, produced by the northwestern clover seed producing area; Louisiana S-1, an intermediate type produced by the Louisiana Agricultural Experiment Station, Baton Rouge; and Nolin's Improved Louisiana White Clover, an intermediate type produced by W. T. Nolin, Hamburg, Louisiana. Forage yield data from these varieties were obtained from 1968 through 1972.

### **Comparison of Forage Production and Flowering from Seed of Louisiana S-1 Produced in Oregon and in Louisiana**

In 1971, samples of seed were procured from representatives of the Oregon State Seed Improvement Association. Samples were received from different lots of registered and certified seed. These samples of seed were representative of seed produced in Oregon for one, two, and three years. This seed was planted in replicated yield trials arranged so that both forage and seed yields were compared. Each test included an entry of foundation seed produced in Louisiana and one of Tillman Ladino. Four samples of seed were procured from Oregon in 1972, and they were planted in similar yield trials for the 1973 growing season. They represented seed grown in Oregon for one, two, three, and four years and were similarly planted for comparison with seed of this variety produced in Louisiana.

The experimental design was a randomized complete block with four replications, with a plot size of 7 feet square. The forage was harvested with a modified rotary mower to which a screen forage catcher was attached. The mower was set to cut the forage 1 ½ inches above the ground. Blossom counts were made on each plot before harvesting. A 1-foot square quadrant was tossed onto each plot at random and the number of blossoms inside it counted. Three such counts were made on each plot.

### **Effects of Seed Storage on Viability**

In October, 1961, seed of Louisiana S-1 was obtained from a seed grower near Rayne, Louisiana. It was taken from seed lots produced in the 1961 seed harvest. The moisture content had apparently reached equilibrium with the atmosphere.

One-pound samples were taken from this seed and placed in bags made of the following materials: (1) Cotton cloth of medium weight muslin; (2) polyethylene plastic 2 mil., .002 inch thick; (3) polyethylene plastic 6 mil., .006 inch thick, and (4) polyethylene plastic 10 mil., .01 inch thick.



The cloth bags were tied with twine, and the plastic bags were heat sealed. The seed consisting of four bags from each type were separated into four lots. One lot was stored in a metal seed house. The second lot was stored in the forage crop breeding laboratory. Lot 3 was stored in an air-conditioned seed storage room, and Lot 4 was stored in the refrigerator compartment of a seed germinator.

Each seed container was sampled 1 year after storage and for each year afterward for 4 years. The seed was germinated by the Louisiana State Seed Testing Laboratory.

### **Maintaining Foundation Breeding Stock**

Clonal lines were maintained in clonal plots in the field and in the greenhouse. The maintenance of clonal lines followed the standard clover breeding routine. Clonal propagules were transplanted into the center of a plot 14 feet x 14 feet. The clonal lines spread toward the outer boundaries of the plot. For transplanting clones, propagules were taken from the outer edge of the plots. The plots were topped with a rotary mower and the clippings were caught in a wire cage and discarded. Propagules were kept in a nursery for two seasons and then moved to prepared plots.

The synthetic variety was formed by transplanting propagules of each clone into a clone-to-row nursery. About 1 acre was used for the intercrossing block. The clonal lines were transplanted into sets of six rows. The



**Figure 2. — Clone crossing block for the formation of the synthetic variety.**



clonal lines were each assigned a number, the lines were arranged at random, and the sets of rows were replicated from 10 to as many as 20 or more times, depending upon the size and shape of the nursery plot. Breeder seed were harvested en masse from the nursery. The breeder seed were planted at the rate of 1 or 2 pounds per acre in drills 21 inches apart. The size of the blocks for foundation seed was 6 to 10 acres.

## Results

### The Synthetic Variety

The results from these investigations gave rise to the synthetic variety of white clover designated as Louisiana S-1. A synthetic variety, according to Tisdal and Crandall (28), "is a variety that is developed by crossing, compositing or planting together two or more strains or clones, the bulk seed being harvested and replanted in successive generations. By natural intercrossing the strains may be synthesized into a new variety." A synthetic variety can be increased through successive seed generations as long as the desired characteristics of the variety are retained. In alfalfa, they reported that clones selected for high combining ability by the polycross method produced a synthetic variety having a significantly higher forage yield than standard varieties or low combining clones chosen by the same technique. The clones selected for use in the synthetic variety were chosen for persistence, vegetative vigor, and combining ability.

The forage yields from polycross progenies, common Louisiana white clover, common Ladino, and the synthetic variety are shown in Table 1. It may be noted from the harvest in January that all of the entries lived through the summer after the first year of growth. The differences in forage yield between the polycross progenies and the synthetic varieties were significant, but these differences were less than the differences among the polycross progenies. It may be noted, however, that common Louisiana white clover and Ladino approached the yields of the polycrosses and the synthetic combination more closely during March and May. For June, Ladino was the most productive and Louisiana common was the lowest. For the total yield, the differences between the entries were also significant, but this was largely due to lower forage yields of Louisiana common and Ladino. The forage yields from breeder seed of the synthetic variety were less than that from foundation seed. This has been true throughout the program. Forage production from a synthetic variety may be slightly less than the average yields of the polycross components.

The yield of the synthetic variety when grown in tests with Louisiana common and Ladino is shown in Table 2. The Ladino entry of this test was from seed of common Ladino and was supplied along with seed of Louisiana common white clover by the clover section of the Division of

Table 1. — Forage yield distribution for polycrosses, synthetic varieties, and certain white clover varieties the second year after seeding

Entry	Forage yields, pounds dry matter per acre				
	Jan. 16	March 6	May 8	June 9	Total
S-1 breeder seed	1,111	2,360	3,763	944	8,178
S-1 foundation seed	1,029	2,236	4,099	1,265	8,629
76 Polycross	1,204	2,533	4,205	877	8,819
715 Polycross	1,055	2,600	4,495	1,055	9,205
721 Polycross	1,319	2,569	4,193	899	8,980
723 Polycross	1,212	2,162	4,624	1,399	9,397
726 Polycross	1,325	2,504	4,219	1,399	9,447
Louisiana white	275	2,020	3,752	355	6,602
Ladino	604	1,725	3,555	2,520	8,404
Mean	1,015	2,301	4,100	1,190	8,629
LSD (5%)	118	302	651	426	1,053

Forage Crops and Disease, U. S. Department of Agriculture. These results were obtained early in the program and are presented to show the relationship between the yield of Louisiana S-1, Ladino, and Louisiana common white clover. After the synthetic variety was released for seed production and became spread over the state, it was no longer possible to procure seed of Louisiana common for comparative testing. Consequently, recent comparisons of Louisiana S-1 with common white clover were not available. Fields of common white clover overseeded with Louisiana S-1 would, of course, be influenced by the improved variety.

Total forage yields for 1951, 1952, and 1953, and the average of the total yields for the 3 years, are shown in Table 2. These data do not give the seasonal distribution, but as shown in Table 1 the larger difference between Louisiana S-1 and Louisiana common occurred in June and later in the summer. Ladino produced less during March, April, and May. Forage yields of Ladino exceeded those of Louisiana S-1 in harvests made later than May. Only the total annual yield and the average of the total yields are shown in Table 2. In average total yield, Louisiana S-1 exceeded Ladino by 10 percent and Louisiana common, the variety it was developed from, by 27 percent.

Table 2.—Forage production with cultivars and strains of white clover

Entry	Forage yields, pounds dry matter per acre				% of check
	1950	1951	1952	Avg.	
Louisiana S-1 white clover	8,333	3,427	7,809	6,523	127
Ladino	6,749	3,643	7,577	5,990	117
Louisiana white clover	6,696	3,043	5,632	5,124	100
LSD (5%)	207	294	249		

## A Further Experiment with Polycross Progenies

Results from this experiment are shown in Table 3. Yields of both forage and seed were lower than normal for white clover in this area. This experiment was conducted about 10 years after Louisiana S-1 was released. The comparison shows that the clonal lines that had been carried in the nurseries to maintain their hereditary characteristics did this insofar as could be detected in such yield trials. Unfortunately, neither Louisiana common nor Ladino was included, and a comparison of these could not be made. However, it may be observed from data in Table 3 that differences between the entries for forage production were not significant except for yields from the harvest made in June, 1961. Seed yields of polycross progenies were compared with those of the synthetic variety. Results showed that seed yields were erratic and differed from season to season. In 1961, yields of seed from forage harvested in May were less than from that harvested in June. For the 1962 harvests, yields were much larger in May than in June. Forage yields were less in 1962 than in 1961 for both harvests. The mean yield of all entries for May, 1961, was 4,012 pounds per acre and for 1962 it was 1,993 pounds. In 1961, the first year after seeding, the yield of seed from the May harvest was low. Seedling clover does not bloom as early in the spring as does growth from stolons that lived over from the previous season. Obviously the yields of seed in 1962 came from second-year stolons. Blooming began earlier in the spring, and consequently the yield of seed from forage harvested in May was larger than from forage harvested in June. The low yield in June was most likely due to weather conditions. There were significant differences between the entries at each harvest except that of June, 1962, when yields were so low as to not be representative of normal growth. Such low yields of seed from plots that had not been harvested previously during the season were due to unfavorable weather conditions that occurred after the harvest in May.

## Comparison of Seed Head Size and Fertility of Florets

The differences between entries for either the number of florets or percent of fertile florets were not significant, except for the percent of fertile florets from those sampled in June, 1962. The average number of florets on seed heads from these plots was 66.9, and the average percentage of fertile florets was 60.0 (Table 4). The samples taken from the plots in June, 1962, contained the smallest seed heads and were lowest in percent of fertile florets. Of the factors contributing to seed yield, these, together with the density of seed heads, are most important. The density of seed heads, or the number within a given area, was not determined. Undoubtedly it was low at this last forage harvest. Seed heads of white clover are fragile after the seed are mature, and they do not withstand frequent showers or unusually hot, dry weather well.

Table 3.—Forage and seed yields of the polycross progenies of the clone components and the synthetic variety, first and second year after seeding

Entry	Forage yields, pounds dry matter per acre				Yield of seed, pounds per acre			
	Harvested in May		Harvested in June		Harvested in May		Harvested in June	
	1961	1962	1961	1962	1961	1962	1961	1962
La. S-1 foundation seed	4,458	1,969	3,374	1,416	42	70	77	4
Polycross 76	3,694	2,253	2,468	1,363	64	63	78	3
Polycross 711	4,191	1,942	2,877	1,328	32	56	70	5
Polycross 715	3,605	2,098	2,593	1,323	79	66	90	2
Polycross 721	4,183	1,947	2,895	1,194	58	47	89	4
Polycross 723	4,209	2,022	2,949	1,314	44	49	80	3
Polycross 726	3,747	1,720	2,344	1,207	42	37	52	5
Mean	4,012	1,993	2,786	1,306	51.6	35.4	76.6	3.7
LSD (5%)	—	—	57.0	—	6.0	6.0	21.0	—



Table 4.—Number of florets per seed head and fertility of florets of polycross components and the synthetic variety, 1961 and 1962

Entry	Number florets per seed head				Percent fertile florets			
	Sampled in May		Sampled in June		Sampled in May		Sampled in June	
	1961	1962	1961	1962	1961	1962	1961	1962
La. S-1 foundation seed	73.2	78.0	78.3	57.5	53.0	71.1	65.2	74.5
Polycross 76	70.8	78.9	64.9	55.3	65.7	56.6	54.9	48.5
Polycross 711	67.9	69.7	67.9	53.5	60.8	70.1	61.1	42.1
Polycross 715	61.4	72.6	74.4	58.5	70.1	48.0	77.3	50.8
Polycross 721	66.4	64.6	69.0	54.6	71.2	60.1	64.6	38.5
Polycross 723	64.5	76.4	79.0	64.8	75.7	58.4	64.9	41.3
Polycross 726	66.2	66.2	67.6	54.0	66.3	63.9	54.8	45.9
Mean	67.2	72.1	72.3	56.1	66.4	61.2	63.2	49.1
LSD (5%)	—	—	—	—	—	—	—	10.4

## Forage Yield Trials with Varieties

Varieties of white clover available for planting in Louisiana and the Southeastern Region are not numerous. Forage yield trials with varieties included only five entries. These are not all planted extensively in Louisiana, but were included to provide a comparison of forage yields among the varieties available. Total forage yields of the different varieties from 1968 through 1972 were not significantly different (Table 5). However, one important difference among varieties for Louisiana and other areas of similar latitude is the blooming rate. None of the Ladino-type varieties bloom sufficiently in Louisiana to produce seed for reseeding. With the hazards white clover is subjected to, reseeding is an important characteristic if the crop is desired from year to year. Droughts, insects, and diseases can take a heavy toll of the stands. If not lost entirely, they may be thinned until reestablishment is necessary unless enough seed is produced for reseeding. The reseeding varieties included in Table 5 are Louisiana S-1 and Nolin's Improved Louisiana White Clover.

## Seasonal Forage Yields

Differences between varieties in distribution of forage may be important in selecting a variety to use. Average forage yields from four seasons of harvests made in April, May, and June are shown in Table 6. Harvests were made in August in certain years, but they are not included. Consequently, forage yields are less than those reported in Table 5, and data in Table 6 are from the average for 4 years instead of 5 years as in Table 5.

Table 5.—Forage yields of white clover varieties grown on Olivier silt loam at Baton Rouge, 1968-72

Variety	1968	1969	1970	1971	1972	Average
----- Pounds of hay per acre -----						
Regal	6,636	6,918	5,846	6,995	8,474	6,974
Tillman	5,700	7,656	6,523	6,114	8,835	6,964
Louisiana S-1	5,913	6,967	7,514	6,262	7,775	6,886
Nolin's Improved	5,803	6,908	7,616	5,828	6,890	6,609
Ladino Common	5,494	7,401	6,280	6,251	6,939	6,473
Average	5,908	7,149	6,903	6,188	7,476	6,725
LSD (5%)	121	708	—	—	—	—

Results given in Table 6 show that 53 percent of the forage yield for Nolin's Improved and 50 percent for Louisiana S-1 were taken at the first

Table 6. — Forage distribution of white clover varieties grown on Oliver silt loam at Baton Rouge, average for 1968-71

Variety	April	May	June	Total
----- Pounds hay per acre -----				
Louisiana S-1	3,307	1,990	1,293	6,590
Tillman	2,497	2,309	1,760	6,566
Regal	2,680	2,318	1,470	6,468
Nolin's Improved	3,416	1,918	1,099	6,433
Ladino Common	2,760	2,057	1,318	6,135
Average	2,932	2,118	1,388	6,438

harvest, made in early April. With varieties of the large type, Tillman gave 36 percent of its growth before the April harvest, the yield taken in May was only slightly less, and the June harvest represented 25 percent of the total yield.

Reseeding varieties, such as Nolin's Improved and Louisiana S-1, produced more forage early in the season. Vegetative growth was retarded as the heavy blossoming season approached, while varieties that produced no flowers, and hence no seed, continued vegetative growth when weather conditions were favorable. Selecting a variety for planting from those included in Table 5 and 6 may depend upon the season of the year that the bulk of the forage is desired. The reseeded characteristic also is important in Gulf Coast states because of the probable loss of stands during summer and fall months. A blend of seed from each of the two types might be used if maximum use of clover for pasture is desired.

### Comparison of Forage and Seed Yields from Seed Produced in Oregon and in Louisiana

Forage and seed yields from the first planting are shown in Table 7. Four forage harvests were made, in late March and in May, June, and August. Seed were harvested in June from a test planted principally for seed production. A forage harvest was made in late March from this test, but since it did not differ from the test for forage the results from it are not reported.

Forage yields averaged 3,132 pounds of hay per acre for the early harvest, 1,634 pounds for May, 2,095 pounds for June, and 1,721 pounds for August. No harvest was made in July because the rate of growth in hot weather from a freshly mowed plot is not sufficient to compete with weed growth. The average total yield for the season was 8,592 pounds of hay per acre. At no harvest was there a yield difference in forage that was significant at the .05 level of probability. There were yield differences, but mostly favoring the Oregon seed. Such differences are thought to be due to better



Table 7.—Forage and seed yields from Louisiana S-1 seed produced in Oregon and in Louisiana, 1972

Variety	Date harvested				Total	Yield of seed lbs./A.
	March 27	May 3	June 6	Aug. 23		
	Pounds of hay per acre					
Oregon Certified 1WC83	3,246	1,832	2,121	1,882	9,081	141
Oregon Registered OWC942	3,286	1,703	2,220	1,723	8,932	129
Oregon Registered L75-013	3,216	1,732	2,131	1,585	8,664	154
Oregon Certified OWC101	3,107	1,623	2,011	1,762	8,503	139
Oregon Certified W91WC4	3,186	1,573	1,972	1,713	8,444	171
Louisiana S-1 foundation	3,087	1,523	2,031	1,723	8,364	167
Ladino	2,798	1,513	2,181	1,663	8,155	13
Average	3,132	1,643	2,095	1,721	8,592	
CV (%)	8.0	13.0	19.0	18.0	—	8.6
LSD (5%)	—	—	—	—	—	12.8



Figure 3. — Experimental plots with Louisiana S-1 white clover seed produced in Oregon and in Louisiana; note the uniformity of forage from plot to plot.



developed seed in the northwest. There were differences between certain entries for yields of seed. Locally grown seed produced 167 pounds of seed per acre while an entry from Oregon produced 171 pounds. Ladino gave the low yield of 13 pounds. These experiments were conducted for only 1 year on the same plots. The second planting was made on different plots in the fall of 1972 with additional samples from Oregon.

Results from forage and seed yield experiments planted in the fall of 1972 and harvested during the spring of 1973 are shown in Table 8. These experiments were planted in a block adjacent to those experiments conducted in 1972. Forage harvests were made in April, May, and June. Forage from the seed plots was harvested July 2. Forage production from each cutting did not differ excessively from that in corresponding months in 1972. Total yield was less because the test was abandoned after the June harvest. Represented in these experiments are seed samples from lots produced in Oregon for 2, 3, and 4 years. It may also be noted that none of the entries differed significantly from the plots planted with locally produced seed. There was a significant difference between Ladino and the S-1 entries for the June harvest. Ladino exceeded these entries only for the June harvest. The differences between entries from Louisiana S-1 at this harvest were not significant.

Seed production was low for the 1973 season. The low yield may have been caused by the delayed harvest. It was made July 2, which is late for harvesting seed of this clover at this location. There was a highly significant difference in the yields of seed. Certain entries from Oregon produced

Table 8.—Forage and seed yields from Louisiana S-1 white clover from seed produced in Oregon and in Louisiana, compared in Louisiana, 1973

Variety	Date harvested			Total	Yield of seed, lbs./A.
	April 4	May 12	June		
	- - - - Pounds hay per acre - - - -				
Ladino	2,515	1,585	2,024	6,124	3.8
Louisiana S-1 local seed	2,545	1,697	1,400	5,642	23.3
La. S-1 Oregon, 2nd year registered	2,699	1,677	1,308	5,683	25.6
La. S-1 Oregon, 2nd year certified	2,628	1,727	1,236	5,591	31.5
La. S-1 Oregon, 3rd year certified	2,678	1,616	1,349	5,643	27.6
La. S-1 Oregon, 4th year certified	2,699	1,616	1,441	5,756	17.2
Average	2,627	1,653	1,460	5,739	21.5
CV (%)	20.0	18.6	10.8	—	18.4
LSD (5%)	—	—	204	—	6.0

higher yields than entries from local seed. The entry from the seed sample planted in Oregon for 4 years produced significantly less than the entry from local seed. This may indicate a tendency toward a change in the blooming rate of this variety, but because of the yield of seed from the other entries the change should not be considered excessive. Seed production from Ladino was 3.8 pounds, compared with the average for all entries of 21.5 pounds per acre.

## Blooming Rate

Blooming rate, measured in the number of seed heads per square foot, is shown in Table 9. The blooming rate varies significantly for the counts made during May and June and July, but this difference is not altogether reflected in the yield of seed shown in Table 8. Such discrepancies might be explained by the way the seed heads were counted. No distinction was made between mature and immature seed heads when the count was tabulated. Obviously, the entry with the largest number of immature seed heads at a seed harvest would yield less seed than those with more mature heads.

## Seed Production

Seed production with white clover in Louisiana is a specialty farm enterprise requiring certain technical skills, which may be gained principally by experience. It entails considerably more risk than most other crops under cultivation in the state. Most of the seed of S-1 are produced in the northwestern states, but it is possible to produce a fair yield of good quality seed in Louisiana. Before attempting such an enterprise it would be well to consider certain practices that may or may not apply to other crops. Yields of seed in the humid area of the United States vary from 30 to 200 pounds

Table 9. — Blooming rate of Louisiana S-1 white clover from seed produced in Oregon and in Louisiana, 1973

Variety	Date of count			
	April 4	May 10	June 18	July 2
	- - - - - Number blooms per square foot - - - - -			
Ladino	0	0.25	1.31	1.4
Louisiana S-1 foundation seed	2.8	27.5	58.4	45.9
Oregon, 2nd year registered	4.2	28.0	51.4	41.7
Oregon, 2nd year certified	3.5	24.5	42.7	34.0
Oregon, 3rd year certified	2.5	21.0	43.8	42.3
Oregon, 4th year certified	3.5	25.7	46.4	40.1
Average	2.7	21.1	40.7	34.2
CV (%)	40.0	14.9	11.2	24.0
LSD (5%)	—	4.8	6.9	6.2

per acre (17), but acre yields of over 300 pounds have been produced in Louisiana. Such yields are, of course, the exception, and while they are possible, prospective seed producers would do well to consider the average yields. Sometimes the yields may be less than the average, depending upon weather conditions prior to and during the seed harvesting period.

Producers of seed of an improved variety should begin by planting foundation seed, and from such planting produce registered or certified seed. Standards for the production of registered or certified seed for Louisiana S-1 white clover, as well as other crop seeds, may be obtained by writing the certifying agency of the state. For Louisiana, the certifying agency is the State Department of Agriculture. The standards are set up to safeguard the quality the buyer of certified seed has a right to expect. The quality found in certified seed is the result of the extra precautions taken prior to the time the seed is bagged.

White clover for seed production should be planted on the heavier soil types. The soil should have good water retention capacity, yet be sufficiently well drained to prevent water from remaining on the surface for extended periods. Other factors to be considered in white clover seed production include 1) using adequate quantities of the right kinds of fertilizer and lime, which should be determined from soil tests; 2) preparing the land well to furnish the best type of seedbed; and 3) keeping weeds under control after the clover begins growing. Still other considerations are such things as 1) rate and time of seeding; 2) seed inoculation, particularly on land suitable for producing certified seed as such land should not have produced clover during the previous 3 to 5 years and thus the inoculant would be needed; 3) and adequate supply of pollinating insects; and 4) seed harvesting and cleaning machinery.

Land preparation is more important for a crop that is to occupy the land 3 or more years than for those which occupy the land for only one season. Regardless of the extent to which other practices are fulfilled, white clover planted on a cloddy, loose seedbed is likely to be less productive than it would be needed; 3) an adequate supply of pollinating insects; and 4) seed

Weed control is as essential with a crop such as white clover seed as it is with any other crop. Of course, after the crop is seeded very little cultivation is possible, and growers must resort to mowing and the judicious use of herbicides. Mowing should begin as early as necessary if it is to be used as the method of weed control. Since there has been considerable development in the field, it would be best to consult Cooperative Extension Service or Agricultural Experiment Station representatives regarding use of herbicides in controlling weeds in white clover.

Topping fields of white clover by mowing just before the peak blooming period will likely be necessary to reduce rank growth of forage. Control of dodder (*Cuscuta arvensis*) is not possible by mowing. It is a most objectionable noxious weed and special care should be taken to keep clover fields from becoming contaminated with it. Dodder is more severe during

years when white clover seed is late in reaching maturity. When a field becomes severely infested, it is usually best to plow the crop under and follow it with a cultivated row crop. When the infestation is light, dodder may be destroyed by burning or by spot treating with a herbicide. The field should be inspected early for the presence of dodder, which may be destroyed by cutting the small patches of infested clover with a hand scythe and removing them from the field. Curly dock (*Rumex spp.*) is difficult to control in seed fields if it gets a start. It cannot be controlled by mowing or burning but can be controlled by the use of the herbicide 2-4-D sprayed on the field during the autumnal season.

## Pollination

As previously mentioned, white clover is mostly self-sterile and must be cross-pollinated by insects to produce seed. Fields of wild white clover or pastures may be adequately pollinated for reseeding by wild honey bees and other insects. Where seed production is intended, it is best not to depend upon natural pollination. Marble *et al.* (23) stated that, "Most growers of Ladino clover seed in California now use a minimum of one 'strong' honeybee hive per acre; a few use three or four such hives per acre." A strong hive has brood in not less than seven combs and bees enough to cover no less than 15 frames in a two-story hive (23). This number of hives may be excessive in Louisiana. Farmers considering seed production with white clover should acquire as many bee hives as is practical for pollination. Without adequate pollinating insects, seed set may be low.

## Seed Harvesting

White clover seed may be matured sufficiently for harvesting 4 to 5 weeks after the peak blooming period has passed. The peak of blooming occurs when the decline in vegetative growth rate begins. Seed are mature in a seed head when the supporting stems lose the green color. Harvesting should be done when about 75 percent of the heads in the field are mature. Weather reports should be the determining factor for beginning harvesting when this stage of maturity is reached.

Harvesting is done by cutting the clover with a mowing machine. It is left in the swath until the foliage is dry, after which it is either threshed from the swath by the use of a combine with a windrow pickup attachment or windrowed and threshed from the windrow. With the limited acreage grown on the Louisiana Agricultural Experiment Station farm, a pickup reel has been used satisfactorily. With a narrow-width combine (72 inches



or less), the pickup reel has been used for harvesting either from the windrow or from the swath. For a wide-swath combine (10 feet or more), the mower swaths should be windrowed for the reason that the large combine will leave some of the swaths untouched unless the surface of the ground is perfectly level, and very few fields are. Large combines may thresh two windrows per trip.

Combines were not necessarily designed for threshing small seed, but were built for threshing cereal grain and larger seed. Careful adjustment may be necessary for best results when using these machines with clover seed. Every precaution should be taken to make necessary adjustments as soon as is practical after the threshing operation begins.

### **Cleaning the Seed**

Two types of seed-cleaning machines are usually required to clean white clover seed after it has been threshed with the standard combine or thresher. In one type machine, seed are run over screens which remove foreign material, such as large stems and other substances larger than the seed. This machine is also equipped with an air blast that removes dust and certain of the lighter materials. For complete cleaning of the seed, a second machine is essential. This machine is known as the gravity seed separator. It completes the separation of small pieces of straw, light immature seed, and other material lighter than the seed. Improvements are being made constantly in seed-cleaning machinery. Such machines are costly and operating them successfully requires some skills gained by experience. It will probably be more practical for most seed producers to depend upon commercial cleaners for cleaning their seed. Growers of certified seed should consult the certifying agency for a list of commercial plants that meet the requirements for cleaning such seed.

### **Seed Storage**

Experiments conducted with seed storage showed that viability of white clover seed was maintained for a considerable number of years if seed were packaged in moisture retention containers and stored at 35° to 45° Fahrenheit. Seed stored in cloth bags under ordinary storage conditions lost about 20 percent of their viability during storage for 1 year, and during 5 years of storage the loss in viability was 98 percent. Under cold storage conditions, seed stored in cotton cloth bags lost 14 percent of their viability during 5 years of storage. Seed stored in polyethylene plastic bags maintained viability better under all storage conditions than that in cotton cloth bags.

Obviously, cold storage is best for storing seed of any type. Cold storage with moisture retention bags is best. Seed packaged in heavy polyethylene bags lined with heavy cotton cloth kept in cold storage for 7 years had 90 percent germination with no hard seed.

## Insect Pests\*

Several species of insects attack white clover in Louisiana. Some may reduce both forage and seed yields, while others primarily damage seed and reduce seed yields. Some are general feeders on many species of plants, whereas others are restricted to attacking some species of legumes. A brief description of the most important pests follows.

**Clover head weevil:** The clover head weevil, *Hypera meleus* (F.), is primarily responsible for poor seed yields of white clover in Louisiana. Eggs are deposited in the stems and the larvae are found in the clover heads where they feed on the flowers and developing seed. Their feeding causes small abnormal seed heads and reduces seed production. Adults feed primarily on leaves and apparently cause little damage to the crop. The adult is brown, about three-sixteenths of an inch long, and has three longitudinal whitish stripes along its topline. The full grown larva is legless with a rusty-brown head. Generally it is yellowish with faint brown or bluish longitudinal stripes. The insect overwinters as an adult and deposits its eggs in slits in the petiole or stems during the spring. Only one generation a year occurs in Louisiana.

**Spider mites:** Spider mites are extremely small mites that often damage white clover by feeding on the underside of the leaves where they suck juices from the plant. Infested leaves have yellow patches that range in size from small specks to large areas. A heavy infestation of spider mites can virtually destroy a clover crop.

**Cutworms:** The variegated cutworm, *Peridoma saucia* (Hubner), is the most destructive of the cutworms attacking white clover in Louisiana. It is 1½ to 2 inches long when full grown and may be identified by the four to six yellow spots along the back. Cutworms injure plants by cutting them off at or just below the soil surface. They usually feed at night and hide during the day, frequently in a semi-coiled position near the destroyed plant.

**Aphids:** Two species of aphids, the cowpea aphid and the yellow clover aphid, infest clover in Louisiana. These aphids can be present in large numbers without apparent injury to the plants. They are sap-sucking insects and heavy infestations may cause the plants to wilt and become stunted and discolored. Excretions of honeydew cause the flower parts to stick together in clumps resulting in reduced seed yields.

**Alfalfa weevil:** Alfalfa is the preferred host of the alfalfa weevil, *Hypera postica* (Gyllenhal). Clover is often attacked in Louisiana. Eggs are deposited in the stems. The larvae cause most of the damage by initially feeding in the stems and subsequently moving to the terminal leaf buds of the plants where they feed on the young buds and later on leaves. Their

---

\*Discussion prepared by B. H. Wilson, Professor, Department of Entomology, LSU Agricultural Experiment Station, Baton Rouge.

feeding skeletonizes the leaves, which stunts plant growth and reduces yields of forage and seed. The full grown larva is legless, about three-eighths of an inch long, and green with a brown head and a white stripe along the back. The larvae tend to curl and bring the tip of the head and the abdomen together when held in the hand.

**Clover root curculio:** Larvae of the clover root curculio, *Sitona hispidula* (F), feed on tender roots and chew large cavities in the main roots. Clover roots infested by these insects will often die, especially during periods of dry weather. The larvae are small, grayish-white, footless grubs about one-sixteenth of an inch long that can be found in the roots of infested plants. The adults are small grayish or brownish beetles with short, blunt snouts that eat out rounded areas from the leaves and gnaw on stems and leaf buds during the day.

**Plant bugs:** Plant bugs (*Lygus spp.*) are sap-sucking insects that can greatly reduce seed yields by feeding on flowers and developing seed. Both adult and nymphal lygus severely injure clover, but the nymphs are more serious pests than the adults. Adult lygus are about one-fourth inch long, have four wings that lie flat on the back, and are marked by a distinct "V" on the back just in front of the wings. Nymphs have black spots on their backs. Lygus nymphs are usually green or yellowish-green while adults are light green, various shades of brown, or almost black.

**Other insect pests:** Several other insects may cause damage to white clover in Louisiana. The southern green stink bug, *Nezara viridula* (L), may reduce seed yields by feeding on flowers of developing seed. The corn ear worm, *Heliothis zea* (Boddie), and the tobacco bud worm, *Heliothis virescens* L, also attack seed heads and are capable of substantially reducing seed yield. The fall army worm, *Spodoptera frugiperda* (P. E. Smith), sometimes attacks the foliage in late summer and early fall and may defoliate a field if not controlled.

**Control:** Most of the serious pests of white clover can be controlled with insecticides. Recommendations for insect control are constantly being modified and improved. County agricultural agents should be consulted for latest recommendations. Honey bees and other pollinating insects are very susceptible to some insecticides. Insecticide applications should be made in the evenings or other times of the day when these insects are not active in the fields.

## Summary

The white clover improvement program conducted by the Louisiana Agricultural Experiment Station has resulted in the isolation of superior clonal lines which, when combined into a synthetic variety, have performed sufficiently well to warrant their use during the past 25 years. Originally the synthetic variety, Louisiana S-1, was composed of five clonal lines; a sixth line was added in the release of the variety.



Since the release of Louisiana S-1, thousands of clones have been screened and dozens of clone combinations have been formed into experimental synthetic varieties. However, none has been tested that was considered sufficiently superior to S-1 to replace it, although a number of excellent clonal lines have been isolated and evaluated.

The breeding stock, consisting of six clonal lines, is maintained by the Louisiana Agricultural Experiment Station for the purpose of supplying seed growers with seed that is constant in genetic purity.

Variety tests over a period of years show that varieties that reseed naturally are probably to be preferred in Louisiana over the nonblooming types adapted to areas farther north.

## Literature Cited

1. Anonymous. 1892. Forage crops, grasses, clovers and small grains. Bull. 19. Second series. La. Agr. Expt. Sta. p. 543.
2. Attwood, S. S. and Helen D. Hill. 1940. The regularity of meiosis in microsporocytes of *Trifolium repens*. Amer. J. Bot. 27:730-735.
3. ———. 1940. Genetics of cross-incompatibility among self-compatible plants of *Trifolium repens*. J. Amer. Soc. Agron. 32:955-968.
4. ———. 1941. Oppositional alleles causing cross-incompatibility in *Trifolium repens*. Genetics 27:333-338.
5. ———. 1942. Genetics of self-compatibility in *Trifolium repens*. J. Amer. Soc. Agron. 34:353-364.
6. ———. 1943. "Natural-crossing" in white clover by bees. J. Amer. Soc. Agron. 35:862-870.
7. ——— and J. T. Sullivan. 1943. Inheritance of a cyanogenetic glucoside and its hydrolyzing enzyme in *Trifolium repens*. J. Hered. 24:311-320.
8. ———. 1947. Cytogenetics and breeding forage crops. Adv. in Genetics 1:52-55.
9. Barrett, O. W. and P. B. Gibson. 1975. Identification and prevalence of white clover viruses and the resistance of trifolium species to these viruses. Crop Sci. 15:32-37.
10. Bula, R. J., R. G. May, C. S. Garrison, C. M. Rincken and D. R. McAllister. 1964. Growth response of white clover (*Trifolium repens* L.) progenies from five diverse geographic locations. Crop Sci. 4:295-297.
11. Carrier, L. and K. S. Bort. 1916. The history of Kentucky bluegrass and white clover in the United States. J. Amer. Soc. Agron. 8:256-266.
12. Clark, D. C. and L. N. Bass. 1975. Effects of storage conditions, packaging materials and moisture content on longevity of crimson clover seed. Crop Sci. 15:577-580.
13. Erath, A. G. 1924. White clover (*Trifolium repens* L.) A monograph. 150 pp. Duckworth and Co., London.

14. Gibson, P. B. 1957. Effect of flowering on the persistence of white clover. *Agron. J.* 49:213-215.
15. ———, G. Beinhart, J. F. Halpin and E. A. Hollowell. 1963. Selection and evaluation of white clover clones: I. Basis for selection and a comparison of two methods of propagating for advanced evaluations. *Crop Sci.* 3:83-86.
16. ———. 1964. A technique requiring few seed for evaluating white clover strains. *Crop Sci.* 4:344-345.
17. ——— and E. A. Hollowell. 1969. White Clover. *Agr. Handbook* 214. U.S.D.A., A.R.S. 33 pp.
18. ——— and G. Beinhart. 1969. Hybridization of *Trifolium occidentals* with two other species of clover. *J. Hered.* 60:93-96.
19. ———, Chi-Chang Chen, J. T. Gillingham and O. W. Barnett. 1971. Interspecific hybridization of *Trifolium uniflorum*. *Crop Sci.* 11:895-899.
20. Halpin, J. E., P. B. Gibson, G. Beinhart and E. A. Hollowell. 1963. Selection and evaluation of white clover: II. The role of midsummer diseases. *Crop Sci.* 3:87-89.
21. Harlan, Jack R. 1956. Theory and dynamics of grassland agriculture. D. Van Nostrand Company. Princeton, New Jersey. 91-94.
22. Lyon, T. L. and J. A. Bizzell. 1911. A heretofore unnoticed benefit from growing legumes. *Cornell Agr. Expt. Sta. Bull.* 294. 11 pp.
23. Marble, B. L., L. G. Jones, J. R. Goss, R. B. Jeter, V. E. Burton and D. H. Hall. 1970. Ladino clover seed production in California. *Cal. Agr. Expt. Sta. Cir.* 554. 33 pp.
24. Owen, C. R. 1953. Louisiana S-1 white clover. *La. Agr. Expt. Sta. Bull.* 479. 15 pp.
25. Piper, C. V. 1927. Forage crops and their culture. The Macmillan Company, New York. 473-479.
26. Singh, Sardar. 1950. Behavior studies of honeybees in gathering nectar and pollen. *Cornell Univ. Agr. Expt. Sta. Memoir* 288. 56 pp.
27. Smith, R. H. and P. B. Gibson. 1960. The influence of temperature on growth and nodulation of white clover with bean yellow mosaic virus. *Agron. J.* 52:5-7.
28. Tisdal, H. M. and Bliss H. Crandall. 1948. The polycross progeny performance as an index of combining ability of alfalfa clones. *J. Amer. Soc. Agron.* 48:293-306.